FINAL REPORT
NOAA Award Number NA03NOS4260204

Project Title:
Marine Resource Conditions for Reef Fishes and Seagrass Around St. John, US Virgin Islands: Historical to Present

Cooperative Agreement between NOAA/NOS and Jacksonville University

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EXECUTIVE SUMMARY

The primary objectives of this project were to compile and summarize historic fish/fisheries data and seagrass data collected around St. John, provide a report of the summary and history of data collected, and provide compiled datasets. Literature and available data were reviewed from numerous sources for this project.

The report consists of two sections: **I. Reef fisheries and reef fish assemblages**, and **II. Seagrass Communities**. The report summarizes the primary sources of information and data on significant and long-term sampling/monitoring efforts for fishes and seagrasses around St. John. Review of additional literature on small projects that have been conducted around St. John was beyond the scope of this project. Reference lists of related literature on marine investigations around St. John have been compiled by the US National Park Service (NPS).

Nearshore resource declines around St. John have been documented in recent years in several reports and publications (see Rogers and Beets 2001, Beets and Rogers 2002, Muehlstein and Miller 2002, Beets and Muehlstein 2003, Beets and Friedlander 2003). Information provided in this report extend the findings of the previous investigations by providing a longer term view of marine resource change. The most significant result is increased evidence of **serial overfishing** that has occurred around St. John over several decades. The evidence of serial overfishing around St. John include the following symptoms:

- Loss and abundance declines of large predators
- Loss and abundance declines of large-sized species
- Abundance and biomass declines of numerous species
- Changes in trophic structure
  (decrease in large predators, increase in herbivores)

The NPS Inventory and Monitoring Program has assumed responsibility of the monitoring efforts established prior to program development. Monitoring projects conducted by NPS in collaboration with cooperators (e.g., NOAA/NOS/CCMA/Biogeography Program) should provide future long-term monitoring data on reef fishes and seagrasses within Virgin Islands National Park, Virgin Islands Coral Reef National Monument, and around St. John. Future assessments should provide more quantitative analyses for evaluating trends.

Reef fish and seagrass datasets were combined into a single MS Access database. Information on these datasets has been provided in Appendix I & II.

I. REEF FISHERIES AND REEF FISH ASSEMBLAGES

BACKGROUND

Throughout the tropics, large changes in reef fisheries and reef fish assemblages have been noted, but commonly have not been quantitatively documented. This is certainly true for the US Caribbean, even though local programs, supported with federal funding, have been collecting data for decades. Most marine monitoring programs were established for harvested species. Fisheries investigations around St. John have been reviewed in previous reports (Rogers and Teytaud 1988, Beets 1996) and are summarized under 'Reef Fisheries' to provide a historic account of the Virgin Islands fishery, which has strongly influenced reef fish assemblages in the Virgin Islands. Monitoring projects of the entire assemblage of reef fishes around St. John have only been conducted during recent years, however, sampling of reef fishes around St. John has been conducted for decades as described under 'Reef Fish Assemblages'.

Reef Fisheries

The history of the small, insular tropical fishery in the US Virgin Islands has been relatively well documented. Early fishery investigations of the US Virgin Islands, that included St. John, described a very modest, subsistence fishery (Fiedler and Jarvis 1932). Throughout most of the 20th century, the fishery was not heavily capitalized with the gear mainly limited to nearshore harvest. The fishery expanded greatly in the 1950s and 1960s as tourism and the local population grew.

The US Virgin Islands legislation has required commercial fishing reporting since the 1970s, but data have been unreliable due to weak enforcement and lack of reporting validation. Catch reports have only differentiated landings by taxonomic groups (not to species) in recent years, and effort data by gear types are unreported with only crude estimates of effort possible. Estimated fisheries landings have been relatively constant over the reporting period, but summary reports have inadequately documented changes in effort and species changes in landings. Regardless, symptoms of **serial overfishing** have been documented.

Recognition of the changes in the Virgin Islands fishery was made in the 1970s, as large growth in tourism increased demand. Fishery status reports stated that most species were stable or declining in catches (Swingle et al. 1970, Brownell 1972), and symptoms of overfishing were documented, such as the loss of the spawning aggregation of one the most important species in the fishery (Nassau grouper; Olsen and LaPlace 1978). In a fisheries assessment conducted in 1977, Dammann and Sylvester stated that the reef fishery was "nearing or at maximum level of sustainment" and that "future levels of fishing effort cannot be increased without seriously depleting remaining stocks."
In the 1980s, several publications reported declining conditions within the US Virgin Islands fishery. In an analysis of commercial landings data collected in 1984-5 in the US Caribbean [Puerto Rico and US Virgin Islands], Bohnsack et al. (1986) noted the rare

occurrence of two target species, which had been documented as common in landings in the 1920s (Nassau grouper and mutton snapper). In 1985, the Fisheries Management Plan for reef fishes in the US Caribbean stated that reef resources were heavily exploited or over-exploited and provided the first reef fish restrictions for federal waters (Caribbean Fisheries Management Council, 1985). The deteriorating status of the reef fishery in the US Virgin Islands elicited a symposium held on St. Thomas in 1987 ('Fisheries in Crisis', deGraaf and Moore 1987), which was developed to exchange information between fishermen and invited scientists and managers. Fishermen and scientists provided a very informed view of the declining conditions of fishery resources and associated habitats.

Continuing reef fisheries declines in the US Virgin Islands have been documented to the present. An evaluation of the US Caribbean reef fish fishery concluded that for the US Virgin Islands catch per unit effort had declined as fish trap effort had increased, abundance of large fishes of many species had declined, average size of several species had declined, and catch composition had changed (Appeldoorn et al. 1992). Many species were apparently overexploited in the reef fishery. Additional analyses of target species (grouper and snappers) presented similar conditions of declining sizes and abundance of large fishes (Beets and Friedlander 1992, Beets et al. 1994, Beets and Friedlander 1999). Changes in catch composition were documented for offshore resources, as well as for protected inshore resources within Virgin Islands National Park (Beets 1997).

Evaluations of the fishery around St. John have been funded by the National Park Service since an initial evaluation conducted in 1958 (Idyll and Randall 1959). Rogers and Teytaud (1988) summarized the work conducted prior to 1988 (including the numerous Biosphere Reserve Research Reports, 1984-1987) and concluded that fish populations had declined drastically. An intensive investigation of the fishery around St. John was conducted from 1992-5 (Beets 1996). Although the inshore fishery around St. John was shown to be small-scale (20-30 commercial fishermen), declines in the fishery were evident. Fishing activity was documented inside and outside park boundaries, and evaluations have shown that the national park has not provided significant protection for many marine resources, particularly for reef fishes (Beets 1996, Rogers and Beets 2001, Beets and Rogers 2002).

Other harvested resources have shown similar declining trends as observed in the reef fish fisheries around St. John. Queen conch (*Strombus gigas*) harvest had approached or exceeded sustainable yield in the US Virgin Islands by the early 1980's (Wood and Olsen 1983; Appeldoorn 1992). In response to severe overfishing of conch in the US Virgin Islands, several management strategies were implemented for improvement of stocks (Beets and Appeldoorn 1994). A 5-year moratorium was established on the islands of St. Thomas and St. John from February 15, 1988 to December 31, 1992. Current USVI government regulations allow a maximum of six conch per person per day (maximum of 24 conch per boat) for recreational harvest and 150 conch per boat for commercial fishermen.

Status of the queen conch stocks in the northern US Virgin Islands was investigated in 1981 (Wood and Olsen 1983), 1985 (St. John only - Boulon 1987), and 1990 (Friedlander et al. 1994). Friedlander et al. (1994) documented significant declines in conch abundance between 1981 and 1990. Data on adult conch densities around St. John were available from 1981, 1985, 1990, and 1996 (Friedlander 1997). Adult densities of queen conch were slightly lower in 1996 compared to 1990 and much lower than observed in 1981 and 1986. Despite over 30 years of regulations within Virgin Islands National Park (maximum take of two conch per person per day), no difference in conch abundance was detected for transects conducted within the national park and other sites around St. John.

Other data sources may supplement our understanding of changes in the reef fisheries resources around St. John. Archeological data provide a view of the harvested resources by indigenous people, which does include marine species (Lundberg 1985, Wild 1989, Wild et al. 1991). Archeological data can be quantitatively collected and analyzed to establish community change and taxonomic size shifts, as has been shown for selected sites in the Caribbean region (including St. Thomas, US Virgin Islands, Wing and Wing 2001). However, few zooarcheological analyses exist for St. John. Plantation-era harvest records were also maintained on some estates and may provide additional comparative information when systematically analyzed (G. Tyson, pers. comm.). Archived data are available, but await analyses to enhance our historical understanding of resource change.

Fish Assemblages

The earliest scientific data collected on reef fishes in the US Caribbean (Puerto Rico and the US Virgin Islands) were species descriptions, inventories, and fisheries surveys (Wilcox 1899, Evermann and Marsh 1900, Nichols 1929, 1930, Fiedler and Jarvis 1932). Most early effort was devoted to Puerto Rico, but active fisheries, especially for large reef fishes (groupers/snappers), were documented for all larger islands. Inevitably, increasing fishing effort around these islands led to resource declines, reviewed in the previous section, but resource species declines also affected the entire fish assemblage structure. Human and natural impacts on resources provided impetus for the establishment of monitoring programs.

The US National Park Service (NPS) has been developing marine monitoring projects around St. John and Buck Island, St. Croix for important resources for over 20 years. In 1982, NPS provided funding for the establishment of the Virgin Islands Resource Management Cooperative, which managed numerous research projects including initiation of reef fish monitoring around St. John (Boulon et al. 1985, Boulon 1986a, 1986b, 1987). Monthly monitoring of reef fish assemblages was conducted at two sites from November, 1988 to May 1991 (Beets and Friedlander 1990, Beets 1993). In 1989, following Hurricane Hugo, NPS initiated annual monitoring at several sites around St. John, which has been continued to present. Beets and Friedlander (2003) provided a comprehensive review of reef fish monitoring around St. John and provided an analysis of the 1989-2000 visual monitoring dataset.

In the recent analysis of reef fish monitoring data collected around St. John (with emphasis on Virgin Islands National Park), 1989-2000, numerous significant abundance declines for reef fish species were documented for the period of analysis (Beets and Friedlander 2003). However, several species that were historically common in landings, such as the Nassau grouper, demonstrated no significant trend over the monitoring period. The reason, of course, was that their abundance over the 12-year monitoring period was too low to show significant trends. The large abundance declines for many species, such as Nassau grouper, occurred before monitoring projects were initiated.

One of the goals of this project was to collect available reef fish datasets for the island of St. John, especially from previous monitoring efforts, and to summarize the findings. In order to provide the historical perspective of data collection on reef fisheries and reef fish assemblages around St. John, collected information and data were separated into three sections: 1) Collection data recorded by J. Randall and colleagues, 2) Fish trap data from various investigations, and 3) Visual sampling data from investigations and monitoring projects. Randall and colleagues collected numerous data sets using various gear and provided the greatest source of historical data collected. Fish traps are one of the most important fishing gears used in the Caribbean and are very useful quantitative sampling gears. Fish trap data allow for excellent temporal comparisons, although sampling bias should be carefully evaluated. Visual sampling provides data on a greater number of species in the reef fish assemblage than most other methods and is non-destructive. The National Park Service initiated reef fish monitoring using visual sampling in the mid-1980s, allowing for analysis of trends for many species.

METHODS

Literature and data sets on reef fishes/fisheries and seagrasses were reviewed in libraries and archives at Virgin Islands National Park, Government of the Virgin Islands-Department of Fish and Wildlife, University of the Virgin Islands, University of Miami. The most comprehensive archive of literature and data for St. John is located in offices of the Virgin Islands National Park.

Data sets were selected for inclusion in the final database based on their relevance and significance **(Table 1; Appendix I).** Selected data sets were included in analyses for this report. Numerous sites around St. John have been sampled, with most important sites presented in **Figure 1.**

<u>Collection Data - J. Randall and Colleagues</u>

John Randall and colleagues from University of Miami conducted their renowned work on St. John from November, 1958 to July, 1961 (Randall 1961). During this productive research period, Randall kept detailed notes on fishes collected. Copies of his field notes, reports, and publications are on file at Virgin Islands National Park (VINP) and University of Miami, Rosenstiel School of Marine and Atmospheric Science (RSMAS). Data on fishes were entered into separate datasets (tables) and combined into one database for this project. Each dataset in the database has the date of collection, location, original scientific name entered by Randall (along with presently used synonyms), number of fish collected per species, and other data, as recorded, including lengths, sex,

Table 1. Description of St. John fish data sets included in the database. Refer to Appendix I for additional information about data sets in the database.

Source	Period of Study	Methods	Location
Randall Field Notes (unpubl.)	1958-1961	Several collection methods; spear, trap, hook/line,ichthyocide	St. John and adjacent islands
Randall 1962, 1963	1959-1962	Tagging, Fish Traps	Lameshur Bays, St. John
Boulon et al. 1986, Boulon 1987	1984-1985	Stationary visual census (Bohnsack and Bannerot 1985); restricted species list	Numerous sampling sites around St. John
Beets and Friedlander 1990	1988-1991	Stationary visual census (Bohnsack and Bannerot 1985)	Cocoloba Cay Reef, Yawzi Point Reef
Beets 1993	1982-83; 1993-94	Fish Traps	Yawzi Point Reef
Beets and Friedlander 2003	1989-1994	Visual census (Kimmel 1992)	Several monitoring sites around St. John (N=18)
Beets and Friedlander 2003	1989-1994	Stationary visual census (Bohnsack and Bannerot 1985)	Four ‘Reference Sites’: Yawzi Point Reef Tektite Reef Haulover Bay Reef Newfound Bay Reef

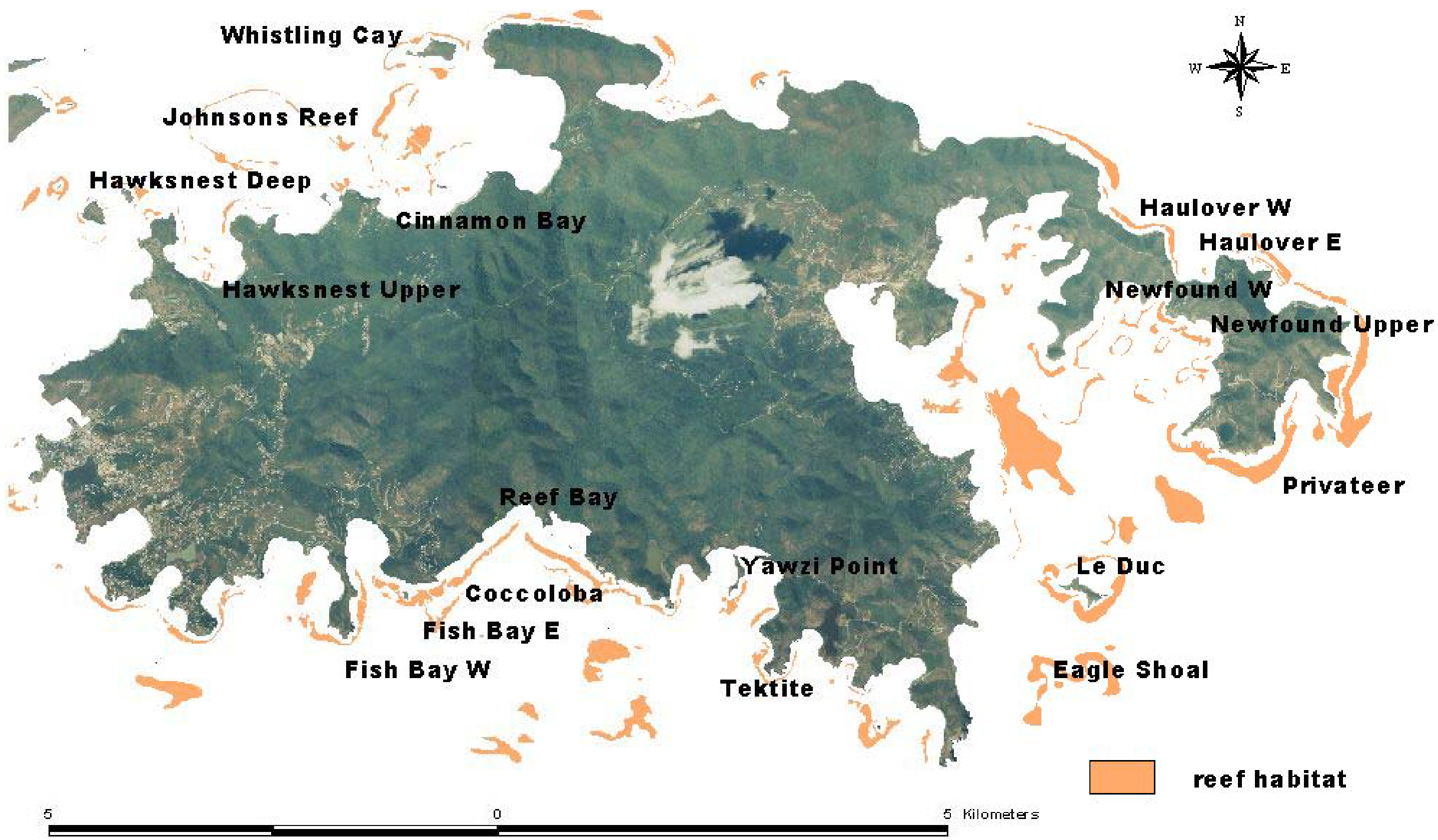


Figure 1. Map of St. John with reef habitat identified and monitoring sites labelled. Map created from NOAA/NOS data.

etc. (information provided in **Appendix I**). Data from Randall's field notes were used for comparisons of proportions of fishes sampled during subsequent investigation. Although most collections made by Randall were not random samples, they provide an interesting comparison to more recent quantitative data. Length data from Randall's field notes were not used for comparisons with other data sets since fishes were collected using several methods with different biases. Length comparisons made during analyses produced varied results due to non-random sampling of most collections.

Randall's field notes were primarily qualitative information and data on fishes collected, but also included a few quantitative poison stations (also referenced in Randall 1961). These data allowed for more quantitative data comparisons with visual monitoring data (1989-2000).

<u>Fish Trap Data</u>
The largest quantitative data set collected by Randall and colleagues was derived from fish trap collections of fishes, which were all measured, tagged, and recorded for a fish growth and movement study from 1959-61 (Randall 1962, 1963). Unfortunately, the fish trap dataset could not be located following searches at VINP, RSMAS, and in Randall's personal files (J. Randall, pers. comm.). Summary data for each species from Randall (1962,1963) were entered for abundance comparisons.

Data from semi-quantitative (Randall 1962, 1963 [4,093 fishes tagged]) and quantitative fish trap studies (Beets 1996; 2 six-month sampling periods: 1982-3 [1,274 fishes sampled], 1993-4 [1,191 fishes sampled]) conducted in Greater and Little Lameshur Bays were combined for a comparative analysis of fish catches among years. Trap data were summarized by species and trophic groups for comparison. Additional quantitative fish trap datasets are available for an offshore location on the insular platform south of St. John but were not available for this report (Caribbean-SEAMAP Program).

<u>Visual Sampling/Monitoring Data</u>
No visual census data were collected by Randall and colleagues. The first visual data sampling for reef fishes conducted systematically around St. John was initiated in 1984 during the Biosphere Reserve Projects (Boulon et al. 1985, Boulon 1987). These projects led to the first visual monitoring data collected in Virgin Islands National Park. The method used during these projects were the standard stationary visual census technique (Bohnsack and Bannerot 1986), although a restricted species/taxa list was employed. Available data from this project were entered, verified, and summarized. Data collected during 1984 were from a large number of reef sites and included in analyses, whereas, data from 1985 were collected from a few sites, which were impacted or low spatial complexity, and not included in analysis. The dataset was included in the database and relevant information presented in **Appendix I.**

Beets and Friedlander (1990) used the standard stationary visual census technique (Bohnsack and Bannerot 1986) for the monthly monitoring project conducted at two reef sites within Virgin Islands National Park from November, 1988 to May 1991. The monthly data were not included in analyses for this report, due to small number of sites sampled (n = 2) with one site (Cocoloba reef) having different substrate type, lower spatial complexity, and different species composition. Graphical representation of monthly variability in parameters were included in this report.

The annual reef fish monitoring project initiated by NPS at 18 reef sites around St. John in 1989, following Hurricane Hugo, employed a modified visual census technique, which was developed and used in Dry Tortugas National Park in 1987 (Kimmel 1992). Monitoring at the sites established in 1989 (originally 18 reef sites were selected with a few omitted and added among years) continued once per year during June/July, using the modified method, until 1994. In 1995, the standard stationary visual census technique (Bohnsack and Bannerot 1986) was employed to continue long-term monitoring at four established monitoring sites (termed 'Reference Sites'). Annual monitoring has continued to present at 'Reference Sites' and at recently established monitoring sites in Coral Bay. This monitoring dataset (1989-2000) was used for the analysis conducted by Beets and Friedlander (2003), and for analyses presented in this report. Data for 1989 from this dataset were excluded from analyses because 1) different methods were being tested and used among sites/zones, 2) samples were collected during a different season (winter) than other monitoring data (summer), and 3) fishes were greatly dispersed following Hurricane Hugo in Sept, 1989, resulting in a very disrupted assemblage structure for many months (Beets and Friedlander 1990). Data from all years and sites were included in the final database.

Database

Reef fish datasets were combined into a single MS Access database. Information on these datasets has been provided in **Appendix I**.

RESULTS

Randall Collection Data compared with Visual Monitoring Data

Historical data collected by Randall and colleagues provided valuable comparative information. For example, John Randall collected numerous fishes of all species for his landmark studies of Caribbean reef fishes around St. John, 1958-1962. Although collection data from Randall's field notes provide few data from quantitative sampling (with the exception of fish poison stations), summary of species relative abundance data provided valuable comparative results.

Large predatory fishes are the species that most commonly demonstrate declines. Groupers and snappers, which are preferred food fishes, have shown large changes in relative abundance around St. John **(Figure 2)**. Large groupers frequently captured by Randall (Nassau, yellowfin, and tiger groupers) were in very low relative abundance in 1989-2000 monitoring data **(Figure 3).** The two smaller-sized groupers, red hind and coney, were much more common in the 1989-2000 monitoring data. Although Randall targeted a few larger species, such as the Nassau grouper, *Epinephelus striatus,* for intensive investigation (Randall 1965), the larger species were apparently in greater

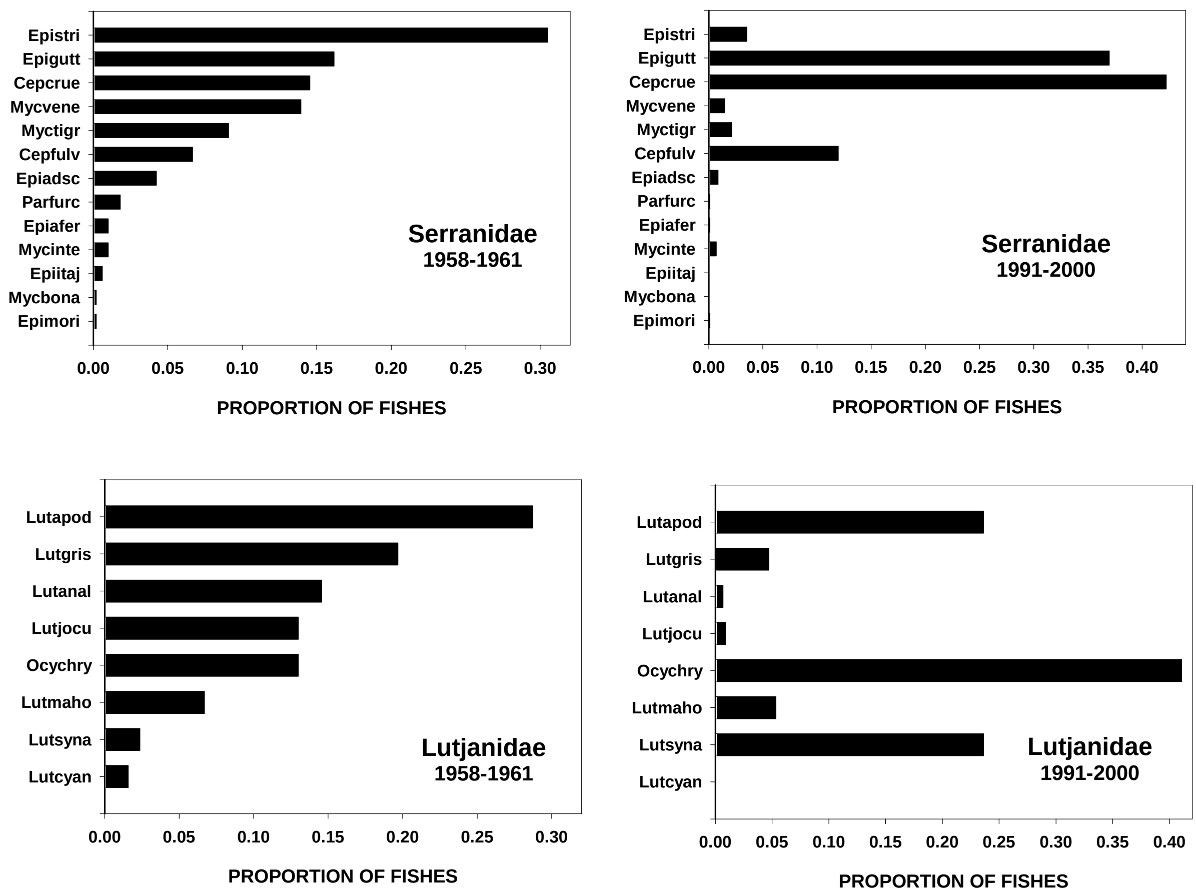


Figure 2. Comparison of the relative abundance of grouper and snapper species collected around St. John by Randall and colleagues (1958-1962) with species observed during visual monitoring (1991-2000).

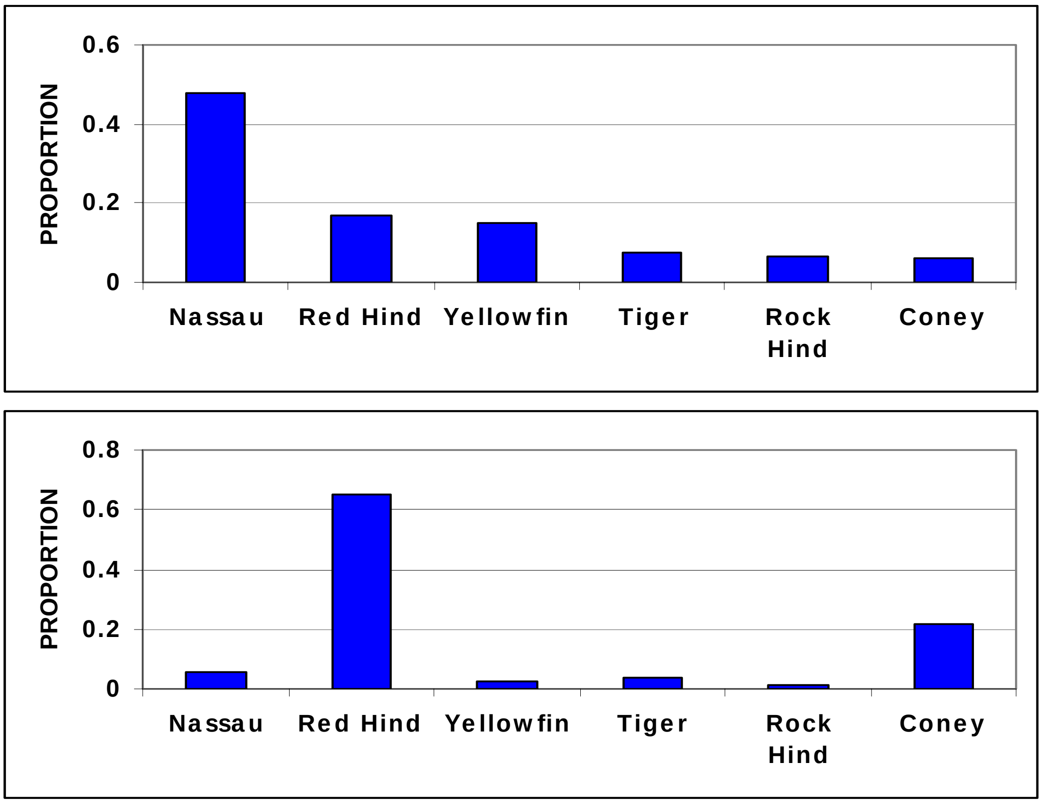


Figure 3. Comparison of the relative abundance of groupers collected by Randall, 1958-1961 (top graph) with groupers sampled 1989-2000 (lower graph) around St. John, US Virgin Islands.

abundance during Randall's investigations. For example, Randall listed 151 Nassau groupers collected in 420 collections (**0.36/collection**) around St. John during 2.5 years (1958-1961), with 63 collected in Greater and Little Lameshur Bays (**0..54/collection**; Randall's field notes) and an additional 124 were tagged in Greater and Little Lameshur Bays (Randall 1962). In contrast, only 67 Nassau grouper were observed in 2,243 visual samples (stationary point counts; **0.03/sample**) taken around St. John from 1989-2000, with only 24 Nassau groupers observed in 437 visual samples (**0.05/sample**) in Little and Greater Lameshur Bays. Additionally, during an annual sampling project on four reefs around St. John, 1994-1999, only 37 Nassau grouper were observed in 32 plot samples (5000 m^2 plot).

Importantly, large-sized species of several herbivores and invertebrate feeders have also experienced large abundance declines. Randall collected and tagged numerous species that are only rarely observed today. For example, over 2.5 years Randall collected 49 margates (*Haemulon album*), the largest Caribbean grunt species, whereas, only 15 were observed in samples from 1989-2000 **(0.007/sample; Table 2).** The two largest herbivorous fishes in the Caribbean, midnight parrotfish (*Scarus coelestinus*) and rainbow parrotfish (*S. guacamaia*), are nearly locally extinct. Randall (1967) recorded the large midnight parrotfish as 'moderately common on Caribbean reefs', but none were observed during the 1989-2000 monitoring period.

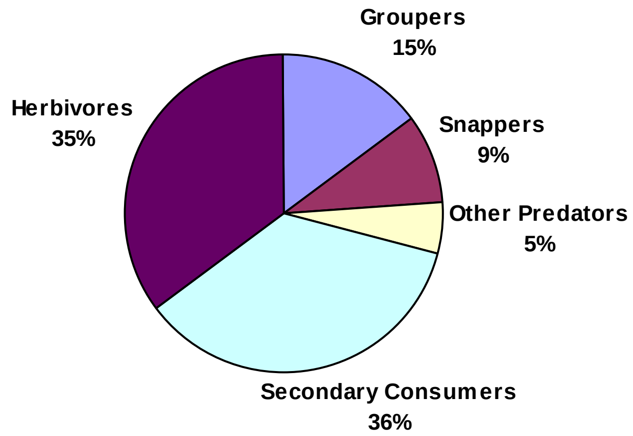
Decreases in lengths of large species were also apparent over the four-decade period. Of the 15 largest-sized reef fishes collected by Randall and colleagues, at least 8 species were larger in 1958-61 collections than observed during visual monitoring, 1989-2000 **(Table 2).** A large bias in this comparison is that large individuals are very difficult to capture, but are easily observed. Randall and colleagues quite probably observed larger individuals than they captured.

The most quantitative comparisons using data from Randall's field notes were made using poison station data. Randall and colleagues made several poison collections with the largest effort being conducted on June 14, 1961 in Greater Lameshur Bay adjacent to Tektite reef, which was one of the 'Reference Sites' during the 1989-2000 monitoring period. The biomass of various taxa of fishes collected in this poison station was very different than the estimated biomass observed on Tektite Reef during 1989-2000 visual monitoring **(Figure 4).** Large predators (groupers and snappers) were a large component of the collection in 1961 (24% of total biomass), whereas, they accounted for only 10% in the estimated biomass from 1989-2000 visual monitoring. Smaller predators and herbivores were also larger components of the assemblage in 1989-2000 visual monitoring data than in the 1961 collection.

Table 2. Comparison of statistics for selected large-sized species collected and tagged by Randall (1958-61) and observed during visual monitoring, 1989-2000. Data for number of individuals were taken from Randall's field notes for St. John only. Frequency data (number of individuals per collection or sample) are given below number of individuals (in bold). Proportions were calculated as number of individuals for each species from all individuals collected/observed for the family. Randall maximum length data were largest listed from all Randall sources recorded as either total or standard length (Randall 1962, 1963, 1967, unpubl. field notes). * Not listed in Randall 1967.

	Randall data (1958-61)			Visual Monitoring data (1989-2000)		
	N freq	**Proportion within family**	**Max Length**	**N freq**	**Proportion within family**	**Max Length (cm TL)**
SERRANIDAE						
Epinephelus striatus Nassau grouper	151 **0.360**	0.305	73.0 TL	67 **0.029**	0.036	85.0
E. itajara Jewfish	3 **0.007**	0.006	165.0 SL	0	0	
Mycteroperca bonaci black grouper	1 **0.002**	0.002	92.0 SL	1 **0.0004**	0.005	45.0
M. tigris tiger grouper	45 **0.107**	0.091	57.2 SL	40 **0.018**	0.022	55.0
M. venenosa yellowfin grouper	69 **0.164**	0.139	85.0 TL	29 **0.013**	0.016	50.0
LUTJANIDAE						
Lutjanus analis mutton snapper	37 **0.088**	0.146	62.0 SL	41 **0.018**	0.006	110.0
L. cyanopterus cubera snapper	4 **0.010**	0.016	99.0 SL	3 **0.001**	0.0004	60.0
L. griseus grey snapper	50 **0.119**	0.196	40.0 SL	282 **0.126**	0.044	45.0
L. jocu dog snapper	33 **0.078**	0.130	63.0 SL	52 **0.023**	0.008	100.0
HAEMULIDAE						
Haemulon album Margate	49 **0.117**	0.219	53.5 SL	15 **0.007**	0.0008	70.0
SCARIDAE						
Scarus coelestinus midnight parrotfish	20 **0.048**	0.043	58.7 SL	0	0	
S. coeruleus * blue parrotfish	12 **0.029**	0.026	44.0 SL	14 **0.006**	0.0002	25.0
S. guacamaia rainbow parrotfish	18 **0.043**	0.039	51.6 SL	3 **0.001**	0.00004	45.0
LABRIDAE						
Lachnolaimus maximus Hogfish	10 **0.024**	0.040	60.0 SL	8 **0.004**	0.0001	70.0
BALISTIDAE						
Balistes vetula queen triggerfish	77 **0.183**	0.962	48.0 SL	145 **0.018**	0.224	45.0

1960 GREAT LAMESHUR BAY POISON STATION



1989-2000 VISUAL CENSUS SAMPLING

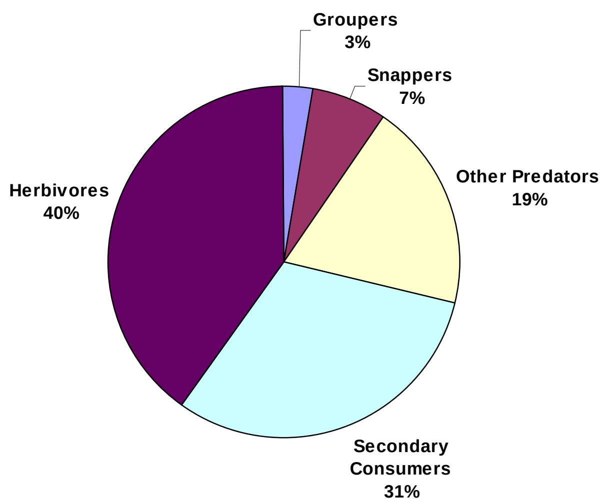


Figure 4. Comparison of the proportion of trophic group biomass between a poison station conducted in Greater Lameshur Bay in 1960 and visual census data collected on the nearest reef to the 1960 sample in Greater Lameshur Bay, 1989-2000.

Fish Trap Data – Randall Data Compared with Subsequent Investigations

Comparison of fish trap data from three sampling periods within the Lameshur Bays, St. John, demonstrate large differences in several taxa and trophic guilds of reef fishes. Randall (1961, 1962) collected a much greater proportion of large predators in fish traps during their tagging studies than were captured during subsequent investigations in 1982-3 and 1993-4 (Beets 1997; **Figure 5**). The proportion of herbivorous fishes was greater in subsequent sampling periods as the proportion of large predators decreased.

The relative proportion of catch for species provided a more detailed perspective of declines among sampling periods (**Figure 6**). Not only was the decrease in large predator abundance apparent as herbivorous species increased, but five large predators captured in sufficient numbers by Randall and colleagues were not sampled during the 1993-4 sampling period.

Although adequate length data from Randall's trap collections were not available, length data for the 1992-3 and 1993-4 trap studies provide an important comparison. The most commonly sampled fishes among trophic groups had significantly greater average length in the 1982-3 samples than in the 1993-4 samples (**Figure 7**).

Visual Sampling/Monitoring Data

The inclusion of 1984 data collected by Boulon (1986, 1987) to the monitoring data collected by NPS and colleagues (Beets and Friedlander 2003) extended trends documented in the latter report. Most taxa and trophic groups did not demonstrate discernable trends. This is partially due to the fact that many species declined in abundance or were locally extinct before the establishment of monitoring programs (refer to comments on large predators in previous section).

Most of the dominant reef fish families (in numbers or biomass) demonstrated no significant trends from 1984 to 2000. However, two important families of reef fishes, surgeonfishes (Acanthuridae) and angelfishes (Pomacanthidae), demonstrated significant declines over the monitoring period, 1984-2000 (**Figure 8, Table 3**). These species of both families increased in landings as large predators declined in the fishery but have probably declined in abundance and/or average length in landings. Surgeonfishes were the dominant family in biomass during the monitoring period. The most abundant surgeonfish species, ocean surgeonfish (*Acanthurus bahianus*), which was second in overall biomass rank and fifth in abundance rank, had significant negative trends for both abundance (least-squares linear regression: $R^2 = 0.69$, $p < 0.003$) and average length ($R^2 = 0.66$, $p < 0.005$). Gray angelfish (*Pomacanthus arcuatus*) was the most abundant angelfish species in the early 1990s and has shown the greatest decline ($R^2 = 0.65$, $p = 0.005$). Interestingly, average length of gray angelfish showed no trend over the monitoring period, but a significant decline in abundance ($R^2 = 0.48$, $p = 0.041$) and average length ($R^2 = 0.63$, $p = 0.018$) was observed for the less abundant French angelfish (*P. paru*).

With the loss and decline of many large-sized species prior to the establishment of visual monitoring projects, most abundant species demonstrated no trends over the monitoring period. However, for large grouper species in sufficient abundance for analysis, three species demonstrated negative abundance trends over the monitoring period (**Figure 9, Table 3**). No large snapper species was sufficiently abundant enough to present trends, with the exception of the coastal pelagic species, yellowtail snapper (*Ocyurus chrysurus*) with no significant trend. A few of the larger-sized species demonstrated positive abundance trends, such as the most abundant grunt species and the queen triggerfish (*Balistes vetula*; **Figure 10, Table 3**). These trends may be a response to decreased predation and/or competition from groupers and snappers.

Finally, it is important to understand the natural variability within the reef fish assemblage, assemblage differences among sites, and influences of natural disturbance. These topics were addressed in the analysis of monitoring data from ‘Reference Sites’ collected from 1989 to 2000 (Beets and Friedlander 2003). The results of one visual monitoring project of reef fishes on two reef sites on the southern coast of St. John provided information on large monthly variability in reef fish abundance and effects of large storms on assemblage structure (**Figure 11**). Impact and recovery responses following storm events were different between the two sites, demonstrating the importance of ensuring sufficient sample size of monitoring sites representing various conditions (e.g., wave exposure).

Summary - Fishes

The comparisons among datasets collected around St. John provide a perspective of the large changes that have occurred in US Virgin Islands fish assemblages over the past 50 years. Tropical reef systems are not the stable systems as described by scientists decades ago, but have assemblages subject to large fluctuations dependent on numerous environmental factors and ecological processes. However, the large changes in trophic structure of the fish assemblage around St. John, with the loss of large individuals, have been documented using several data types and sources.

The large changes in fish assemblages around St. John observed over the past several decades have suggested resource degradation and serial overfishing. Although over-exploitation is certainly not the only factor responsible for the large changes observed in reef fish assemblages, it certainly has been a strong contributor and is a human factor that can be managed.

Table 3. Results of least-square regression analysis for selected taxa of visual sampling data from St. John, 1984-2000. 1984 data were from Boulon (1986, 1987); 1991-2000 data were from Beets and Friedlander (2003). Only 1991-2000 data were used for grunt and queen triggerfish regression analyses to analyze for significant increases.

Taxon	slope	F	P
Families			
Acanthuridae surgeonfishes	-0.465	7.727	0.021
Pomacanthidae angelfishes	-0.043	9.862	0.012
Species			
Cephalopholis fulva coney	-0.013	14.820	0.004
Epinephelus guttatus red hind	-0.015	8.375	0.018
E. striatus Nassau grouper	-0.004	3.764	0.084
H. aurolineatum Tomtate	0.652	10.893	0.011
H. plumieri white grunt	0.021	0.044	0.838
H. sciurus bluestriped grunt	0.055	2.195	0.177
Balistes vetula queen triggerfish	0.003	0.150	0.709

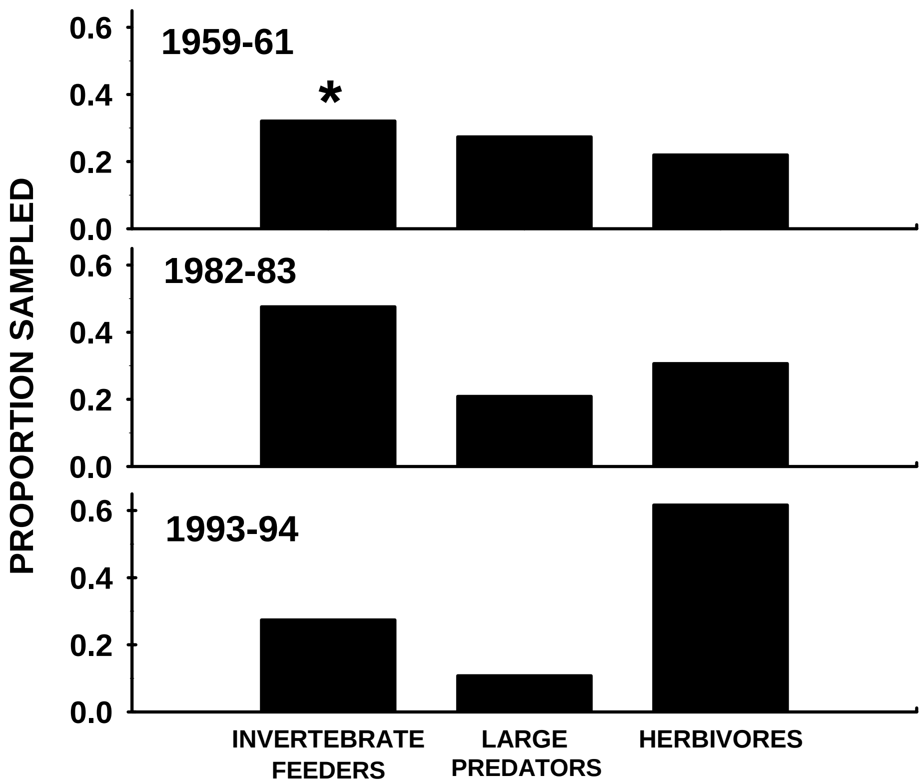


Figure 5. Comparison of the proportion of fishes in trophic guilds captured primarily using fish traps in Little and Greater Lameshur Bays (Randall, 1959-61) with trap catches at Yawzi Point between Little and Greater Lameshur Bays during two periods (1982-3; 1992-93). Invertebrate feeders were primarily grunts and porgies; large predators were primarily groupers and snappers; herbivores were primarily parrotfishes and surgeonfishes. Data for several species were not reported by Randall (1962, 1963), most of which were invertebrate feeders resulting in smaller proportion for that trophic guild (*).

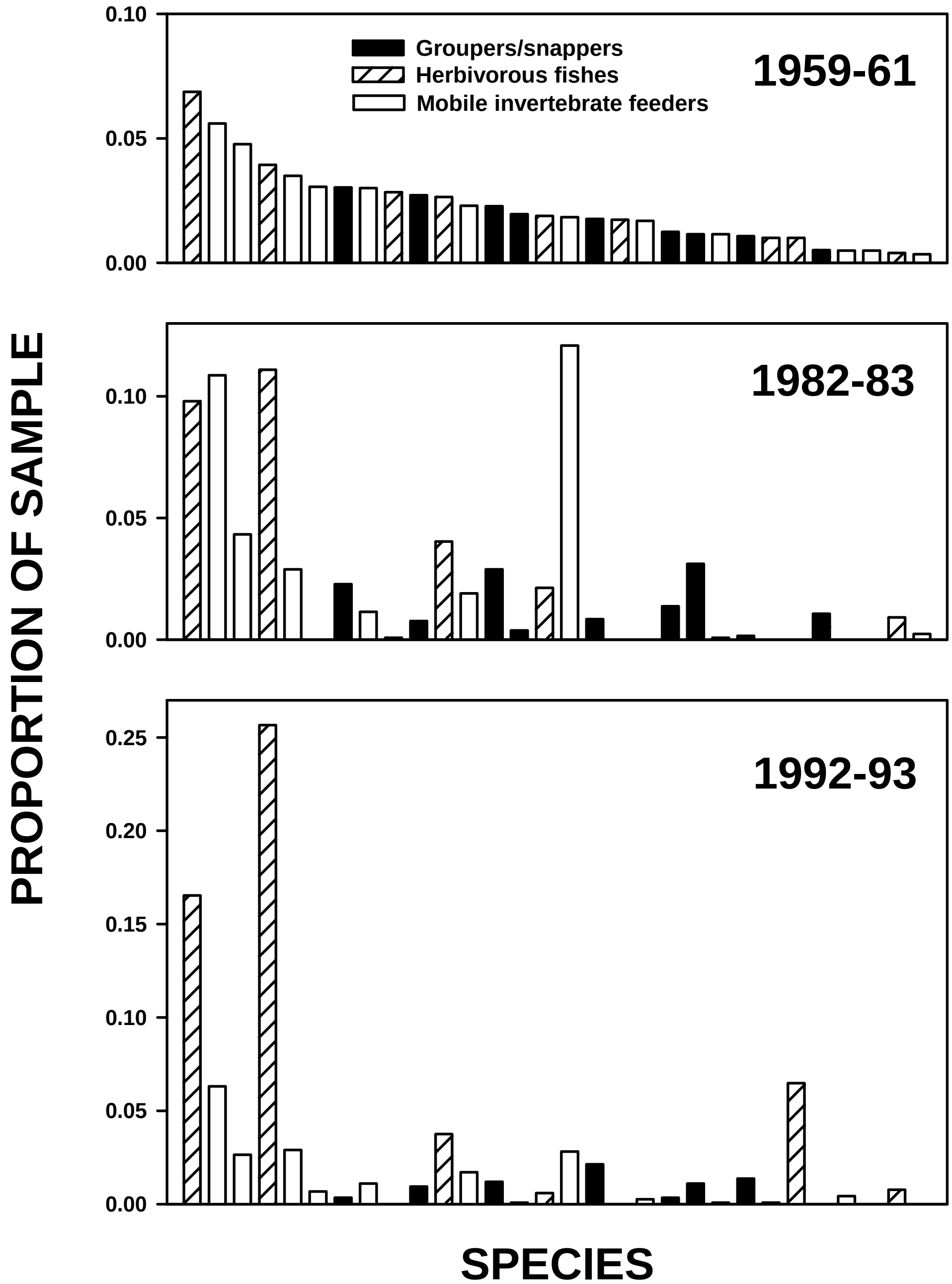


Figure 6. Comparison of the proportion of fishes captured primarily using fish traps in Little and Greater Lameshur Bays (Randall, 1959-61) with trap catches at Yawzi Point between Little and Greater Lameshur Bays during two subsequent periods (1982-3; 1992-93).

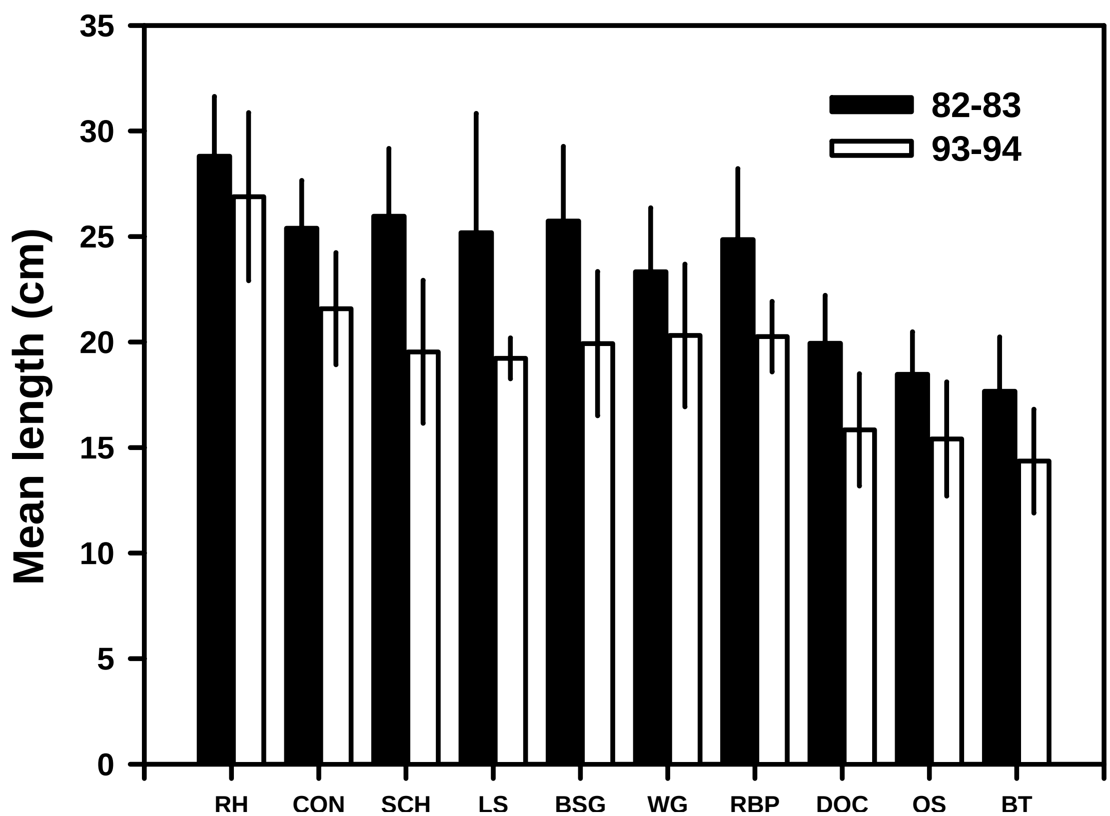
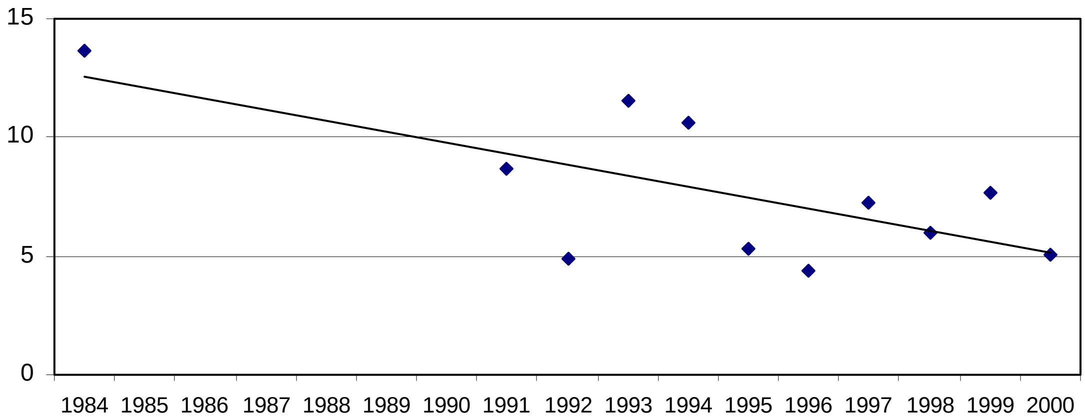


Figure 7. Mean length of fishes in trap samples taken during two six-month periods from Great Lameshur Bay Reef, 1982-3 and 1993-4. These species represented the most commonly caught in different trophic groups: groupers – RH: red hind (*Epinephelus guttatus*), CON: coney (*E. fulvus*); snappers – SCH: schoolmaster (*Lutjanus apodus*), LS: lane snapper (*L. synodus*); mobile invertebrate feeders – BSG: bluestriped grunt (*Haemulon sciurus*), WG: white grunt (*H. plumieri*); herbivores – RBP: redband parrotfish (*Sparisoma aurofrenatum*), DOC: doctorfish (*Acanthurus chirurgus*), OS: ocean surgeonfish (*A. bahianus*), BT: blue tang (*A. coeruleus*). Error bars represent one standard deviation. (From Rogers and Beets 2001)

Acanthuridae - surgeonfishes
Average number per sample



Pomacanthidae - angelfishes
Average number per sample

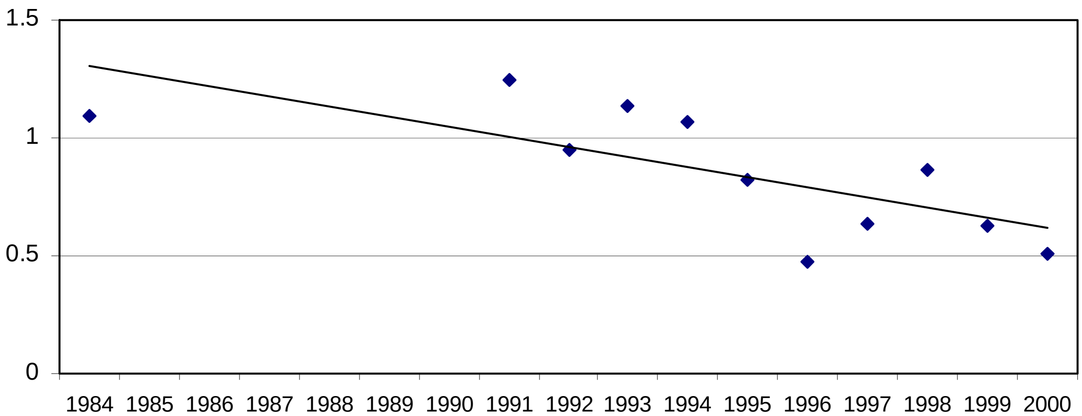


Figure 8. Trends in abundance of surgeonfishes and angelfishes around St. John, US Virgin Islands, from 1984 to 2000.

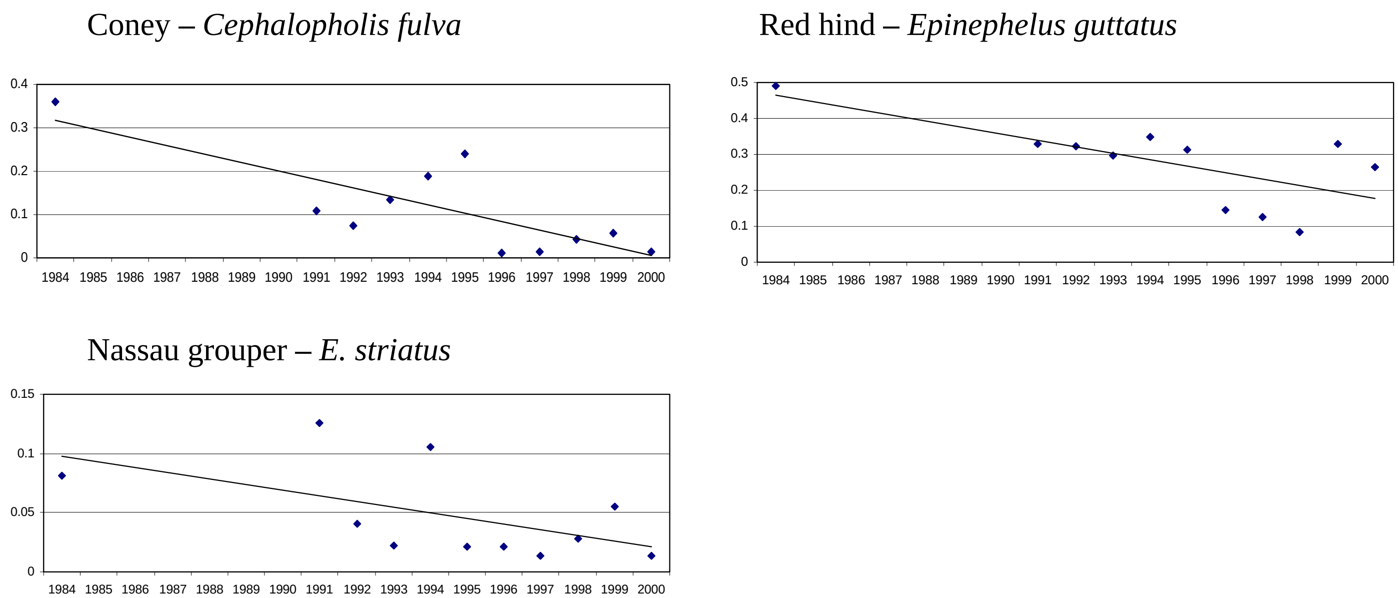


Figure 9. Trends in abundance of three grouper species around St. John, US Virgin Islands, from 1984 to 2000.

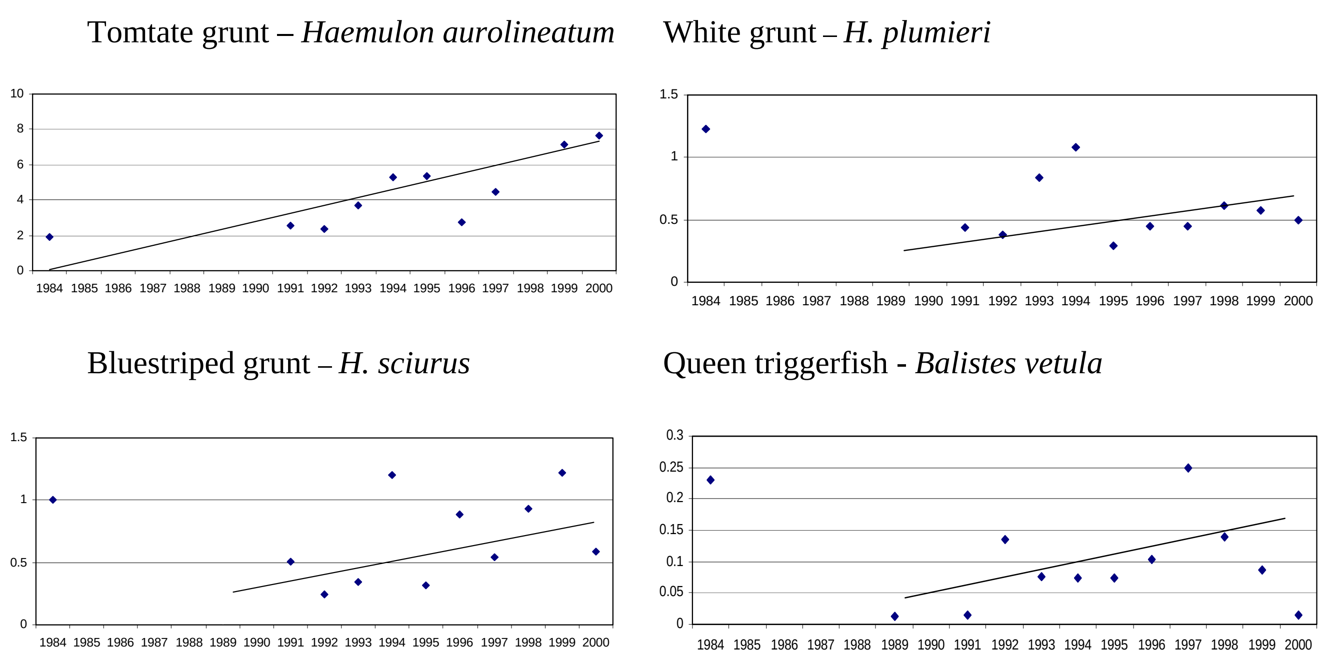


Figure 10. Trends in abundance of three grunt species and queen triggerfish around St. John, US Virgin Islands, from 1984 to 2000.

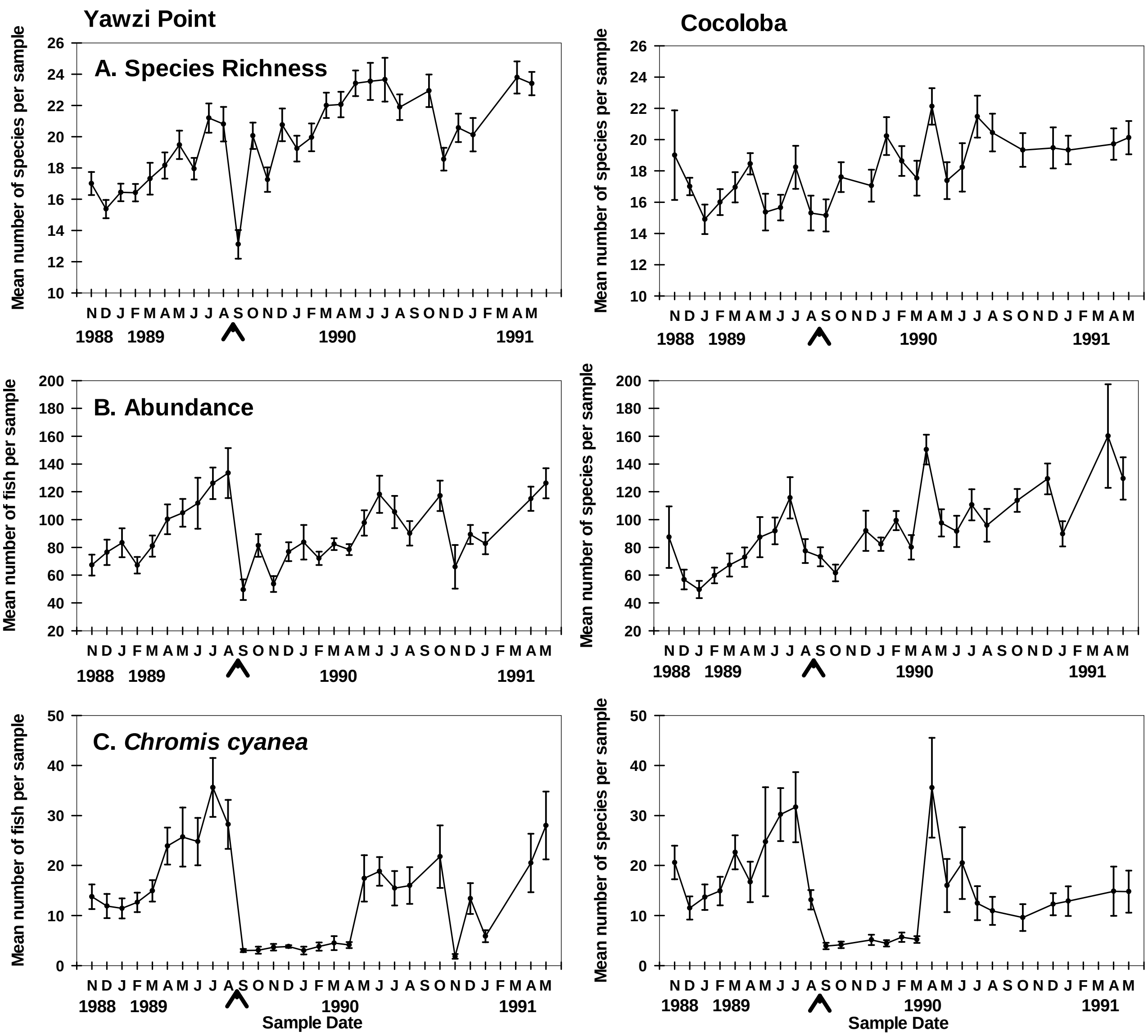


Figure 11. Mean monthly trends in A. Species richness, B. abundance, and C. abundance of *Chromis cyanea* at Yawzi Point and Cocoloba Cay monitoring sites, Nov 1988 – May 1991. Error bars are standard error (average sample size per month = 18). A large tropical storm, later Hurricane Gilbert, affected the southern coast of St. John in Sept, 1988. The arrow marks the passing of Hurricane Hugo, Sept. 1989. (From Beets and Friedlander 2003)

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II. SEAGRASS COMMUNITY STRUCTURE

BACKGROUND

The seagrass communities around the island of St. John are important habitats for numerous marine species within the Virgin Islands National Park (VINP) and the Virgin Islands Coral Reef National Monument (VICRNM). Seagrass communities are closely linked with ecosystem function of coral reefs and coral reef fishes (Lee and McIvor 2002). Seagrasses comprise 18% of eleven different mapped benthic habitat types (National Oceanic Service [NOS] analysis – June 2002), covering over 3 square kilometers within the boundaries of VINP. The seagrass communities are around St. John include at least four species of seagrasses: *Thalassia testudinum*, *Syringodium filiforme*, *Halodule wrightii* and *Halophila* spp.. Historical work by Kumpf and Randall (1961) reported extensive seagrass coverage within VINP but without quantitative data. Beets et al. (1985) mapped benthic habitats around the island of St. John but did not include quantitative seagrass data. Williams (1988a,b) collected quantitative data on seagrass communities in Maho, Francis and Greater Lameshur Bays. Substantial changes in the status of seagrasses within VINP have occurred over the last decade (Rogers and Beets 2001; Muehlstein and Miller (unpubl. NPS monitoring data). The NOS Center for Coastal Monitoring and Assessment has created extensive benthic habitat maps of St. John and have provided quantitative data since 1991 on marine resources (Kendall et al. 2001).

FIELD SAMPLING METHODS

Field sampling and monitoring at various scales provide the most comprehensive view of seagrass conditions and dynamics. Data collection on a larger scale would facilitate analyses of system change (either recovery or decline). Suggestions for community-level seagrass monitoring around the island of St. John include: monitoring existing sites around the island, adding additional sites as resources permit, and utilizing a combination of fixed transects and random sampling methods. Fixed transect monitoring stations have been established in Greater Lameshur Bay, Little Lameshur Bay, Salt Pond Bay and Brown Bay. Randomized monitoring sites (using AquaMap™ methods) were established in Greater Lameshur Bay, Hurricane Hole and Brown Bay, (described by Rogers et al. 2003; Muehlstein & Miller 2002; Miller and Rogers 2002). Annual monitoring efforts at these sites are recommended with data collection of the following parameters: seagrass densities, seagrass community structure, percent cover and average canopy height.

Increased efficiency of sampling to include additional sites within VINP and VICRNM should use a modified Braun- Blanquet survey technique (Braun-Blanquet 1972). This measurement of percent cover is extremely efficient in predicting differences in seagrass cover (Heidelbaugh and Nelson 1996). Fourqurean et al. (2001) and Fourqurean and Rutten (2002) discussed the merits of the Braun-Blanquet survey techniques for rapid assessment and described it as a robust and highly repeatable method. It has been utilized extensively for seagrass monitoring protocols. With this method, a series of quadrats are randomly placed at each location. A diver lists all species within the quadrat and then ranks the abundance of each species according to a predetermined percent cover score (0-5). This modified Braun-Blanquet scale allows cover classes to be broken down into eight categories for statistical analysis (Table 1). Kendall et al. (2001) use a slightly different method for estimating seagrass percent cover with six categories for percent cover. A standard survey technique for predicting percent cover should be derived for all sampling around St. John. Either survey method takes less time than short shoot density counts and provides valuable information on seagrass cover. However, short shoot density counts are also important and should not be excluded. Selected sites need to be geo-referenced on GIS maps and utilized for continued monitoring and comparison.

Table 1. Braun-Blanquet Abundance Scale Used to Assess Seagrass Density (from Fourqurean, Durako, Hall & Hefty, 2002)

Cover	Description
0	Absent
0.1	Solitary short shoot, less than 5% cover
0.5	Few short shoots, less than 5% cover
1	Many short shoots, less than 5% cover
2	5-25% cover
3	25-50% cover
4	50-75% cover
5	75-100% cover

SEAGRASS DATA SUMMARY

Seagrass monitoring projects which have been conducted within VINP include 1) fixed transects in Greater Lameshur Bay from 1990–2002 (Muehlstein, unpubl. data), 2) fixed transects in Little Lameshur Bay, Salt Pond Bay and Brown Bay 1997–2002, (Muehlstein & VINP Division of Resource Management); 3) randomized sampling (AquaMap™ system) in Greater Lameshur Bay (2000-2004), Brown Bay (2001-2004) and Hurricane Hole (Borck Creek; 2001-2004) (VINP Inventory & Monitoring Program); and 4) monitoring of seagrasses around selected moorings at Maho, Leinster, Hawksnest and Francis Bays 2001-2004 (VINP Division of Resource Management).

<u>Greater Lameshur Bay Long-Term Seagrass Monitoring Project (1989-2002)</u>

The seagrass community of Greater Lameshur Bay is a heterogeneous mix of *Thalassia testudinum* and *Syringodium filiforme*. Prior to 1997, no *Halodule wrightii* was present on any of the fixed transects within the bay. Major storm events in 1989, 1995 and 1999 severely impacted the seagrass communities of Greater Lameshur Bay and surrounding bays. Over the last decade other notable changes occurred with the bay and within the watershed area. Anecdotal observations indicated a decrease in water quality within the bay. In 1999 a large macroalgal overgrowth of *Bryothamnion triquetrum* appeared in the northwest quadrant of the grassbed and persisted until 2003. The number of vessel moorings in the bay from five to sixteen. The road into Greater Lameshur and Little Lameshur Bays was paved, altering the flow of stormwater runoff. The activity of the Virgin Islands Environmental Research Station also greatly increased especially in terms of the large size of user groups.

A long-term monitoring project examining changes in seagrass community structure was established in Greater Lameshur Bay in 1989. The study began following Hurricane Hugo, to monitor the status and recovery of seagrasses following a major storm event. Dr. Lisa Muehlstein conducted this study, initially in cooperation with the Caribbean Research Institute (CRI) at the University of the Virgin Islands (UVI) and the Virgin Islands Ecological Research Station (VIERS). Following sampling in 1991, the project was supported as a collaborative research effort with VINP and later as a collaborative research effort with Biological Resources Division of the United States Geological Survey (BRD/USGS). The last three years of this work were funded through a cooperative agreement with the VINP Inventory and Monitoring Program and Jacksonville University.

Three 250-meter fixed transects were established in Greater Lameshur Bay and sampled for seagrass density (0.04m^2 PVC quadrat), seagrass community structure and seagrass percent cover (0.25m^2 PVC quadrat subdivided into 25 squares) from 1989 – 2002. Data collection occurred annually during June and July. Transect one was established at a depth of 3-4 meters originally in a dense *T. testudinum* habitat. The second transect was established at a depth of 4-5 meters with a healthy mix of *S. filiforme* and *T. testudinum*. Transect three established at 5-6 meters depth was primarily *S. filiforme* in the original surveys. Additional information on methods for this investigation is outlined in Muehlstein and Miller (2002) and Beets and Muehlstein (2003). A fourth fixed transect was established in 1998 adjacent toYawzi Reef. Transect four, a deeper transect located in 15-17 meters, was dominated by *S. filiforme* (< 1 short shoot *T. testudinum*/square meter). Storm disturbance events occurred in 1989, 1995 and 1999 resulting in declines of seagrass densities throughout Greater Lameshur Bay.

Long-term fixed transect data analysis for Greater Lameshur Bay confirmed the dynamic nature of the seagrass community relative to storm disturbance events (Figure 1). There were significant changes in short shoot densities of *T. testudinum* and short shoot densities have still not returned to original densities prior to the 1995 storm (Beets and Muehlstein 2003). Seagrass short shoot densities prior to 1995 were similar to densities reported in other work (Williams 1988a,b). A recovery pattern in *S. filiforme* delineated peaks in short shoot densities two years after each major disturbance event although there were no significant changes in densities (Beets and Muehlstein 2003). Increases in short shoot densities of *H. wrightii* were apparent along transect one in 2001 and 2002 (Figure 1).

Densities for *S. filiforme* along transect four were actually the densest of any site sampled around St. John (Figure 2). However, following the storms of 1999, the densities of *S. filiforme* were lower and have continued to significantly decline, with little indication of recovery three years following the storm (Beets and Muehlstein 2003).

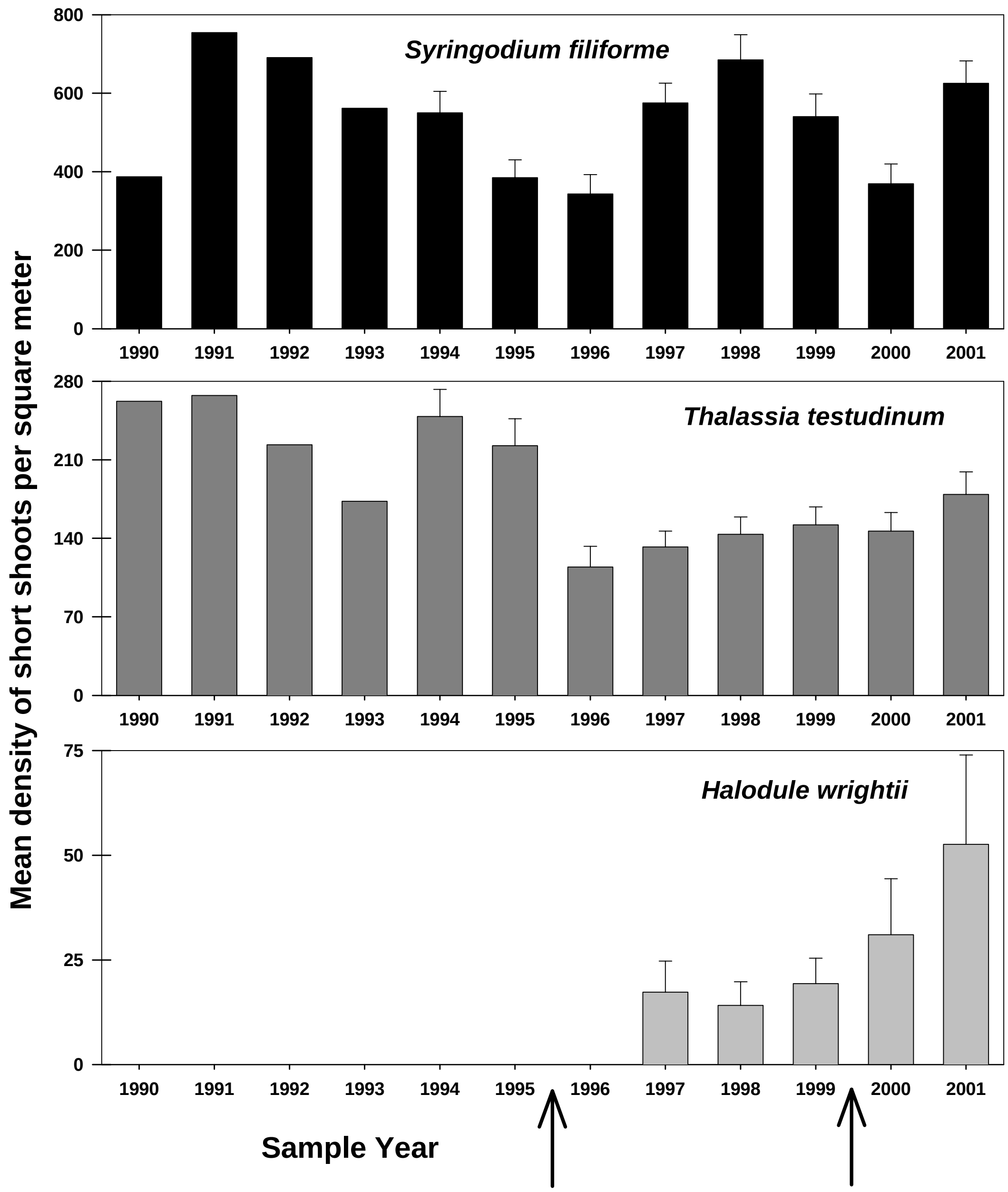

Figure 1. Mean short shoot densities for Greater Lameshur Bay. Error bars represent 1 standard error. N = 73 quadrats. *Thalassia testudinum* - significant negative linear regression among years ($R^2 = 0.85$; $p = 0.01$).

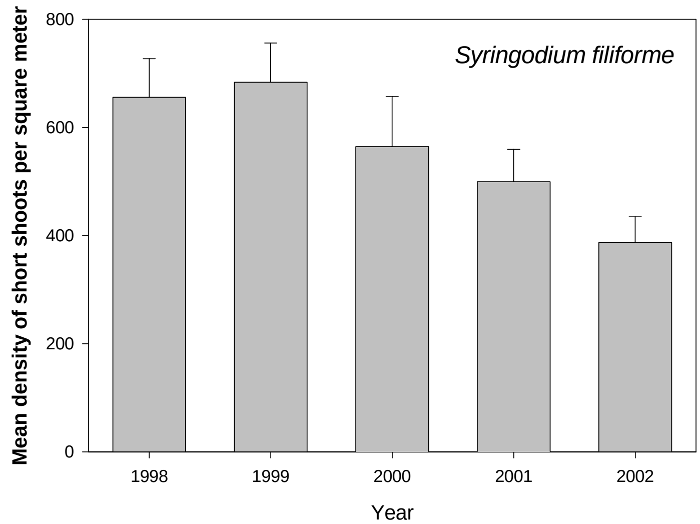

Figure 2. Mean short shoot densities for fixed transect 4, a deeper transect (15-17 m) in Greater Lameshur Bay. Error bars represent 1 standard error, N = 26 quadrats. Significant negative linear regression (R^2 = 0.9; p = 0.01).

Fixed Transects – Little Lameshur Bay, Salt Pond Bay, Brown Bay (1997-2002)

In 1997, the VINP Division of Resource Management expanded seagrass monitoring efforts to include data collection in seagrass habitats of selected bays around the island following the installation of permanent vessel moorings within the park. Fixed transects were established in Little Lameshur Bay, Salt Pond Bay and Brown Bay. Little Lameshur Bay and Salt Pond Bay both had moorings installed whereas Brown Bay did not. Seagrass densities ($0.04m^2$ PVC quadrat) and seagrass community structure ($0.25m^2$ PVC quadrat subdivided into 25 squares) were sampled along a single fixed transect in each bay from 1997 – 2002.

Salt Pond Bay

Syringodium filiforme is the dominant seagrass in Salt Pond Bay (Figure 3). There was a dramatic decrease in short shoot densities over a two-year period, changing from an average of 664 short shoots/m^2 in 1998 to only 111 short shoots/m^2 in 2000. This was presumably due to the impact of hurricanes in 1999 and indicated the very sensitive nature of these seagrass communities. There was a significant change in *H.wrightii* short shoot densities over the sampling period (Beets and Muehlstein 2003). *Halodule wrightii* doubled in short shoot densities from 2000 to 2001 with continued increases in 2002.

Thalassia testudinum was present in extremely low densities in 1999 along a small portion of the transect. *T. testudinum* disappeared in 2000 but did reappear in 2001. Data supported the dynamic condition of this bay still in recovery from storm disturbance. Historical reports (Beets et al. 1985) indicated more extensive and denser seagrass conditions than presently exist.

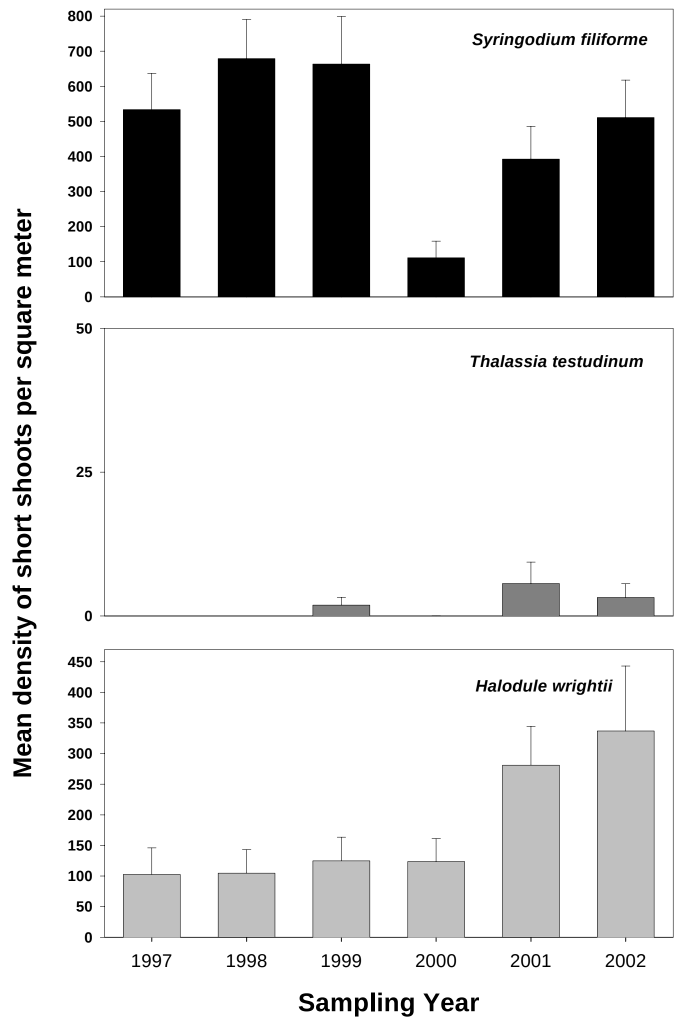

Figure 3. Mean short shoot densities for Salt Pond Bay. Error bars represent 1 standard error. N = 32 quadrats. *Halodule wrightii* – significant negative linear regression (R^2 = 0.8; p = 0.02)

Little Lameshur Bay

The three common species of seagrass in the Virgin Islands were well represented in Little Lameshur Bay (Figure 4). All three seagrass species experienced a decline in short shoot densities in 2000, similar to observations Greater Lameshur Bay and Salt Pond Bay. Changes in seagrass densities were not significant for the 1997-2002 sampling period (Beets and Muehlstein 2003). Although *S. filiforme* was the dominant seagrass in Little Lameshur Bay, densities declined in the 2002 survey, likely a result of successional changes within the seagrass community structure. As short shoot densities of *S. filiforme* were decreasing, the densities of *T. testudinum* and *H. wrightii* increased indicating a continuing recovery of the system.

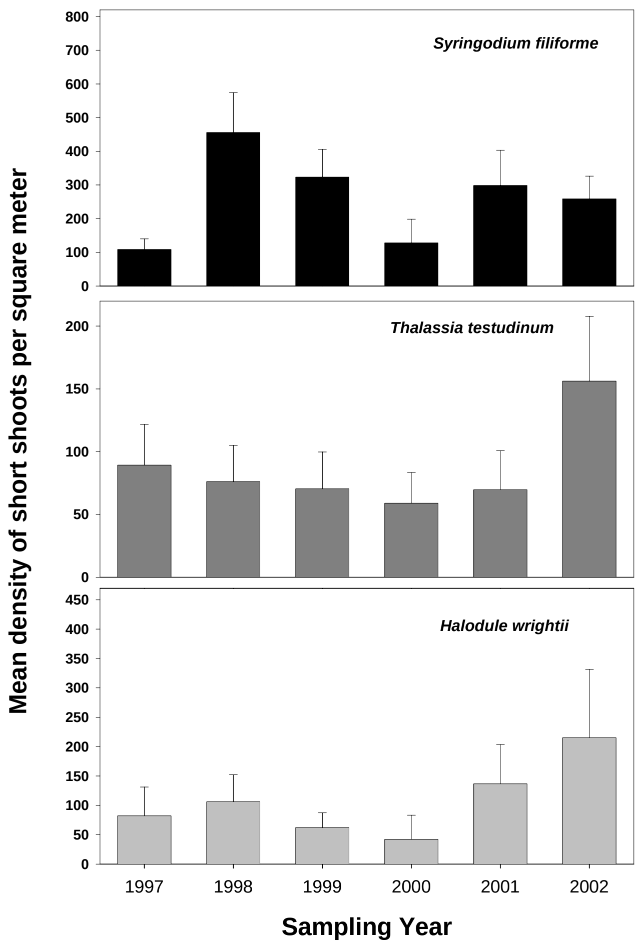

Figure 4. Mean short shoot densities for Little Lameshur Bay. Error bars represent 1 standard error. N = 22 quadrats.

Brown Bay

There is a dense, heterogeneous mix of seagrasses in Brown Bay (Figure 5). *S. filiforme* was the only seagrass to decline in 2000 while *T. testudinum* and *H. wrightii* showed slight increases in densities in 2000. Storms, which passed in 1999 apparently, had less effect in Brown Bay. In 2001 *T. testudinum* had the highest densities in the five years of sampling. Short shoot densities of *H. wrightii* were highest in Brown Bay of all sites sampled around St. John in 1997 but did decrease significantly during the 1997-2001 sampling period (Beets and Muehlstein 2003).

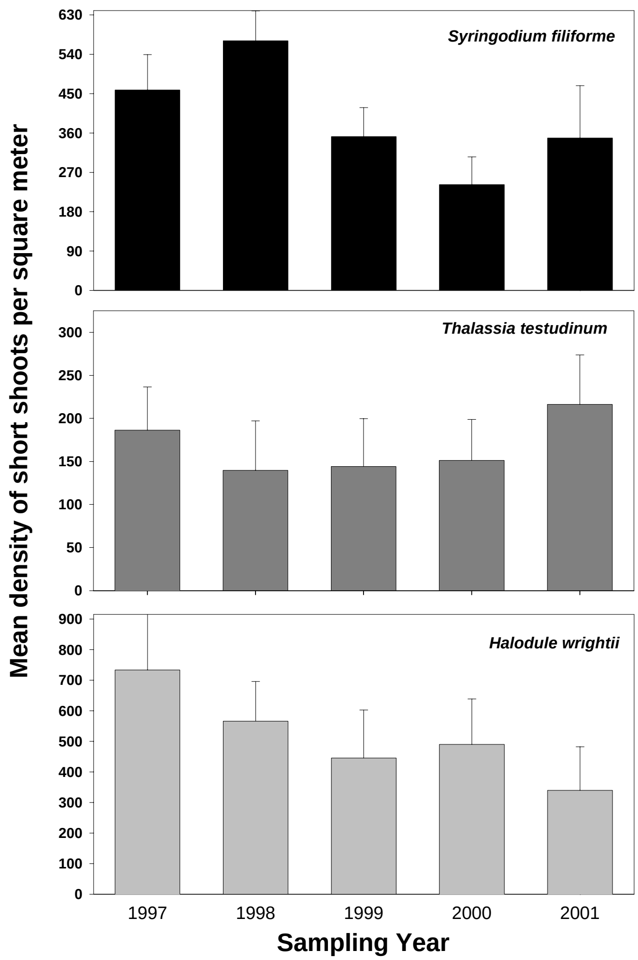

Figure 5. Mean short shoot densities for Brown Bay. Error bars represent 1 standard error. N = 21 quadrats. *Halodule wrightii* – significant negative linear regression (R^2 = 0.9; p = 0.02)

Randomized Surveys (AquaMap™) (2000 – 2004)

In 2000, USGS/BRD implemented a new survey technique using AquaMap™, underwater SONAR equipment, which allowed for expanded, random sampling of the seagrass habitat in Greater Lameshur Bay and accurate underwater point relocation. The intention was for further long-term monitoring at that site and eventually at additional sites around the island. The equipment and methodology had already successfully been established for successful monitoring on coral reefs (Miller & Rogers 2002; Rogers et al. 2003). VINP Inventory & Monitoring Program continued with the AquaMap™ project in 2001. Additional sites at Hurricane Hole (within VICRNM) and Brown Bay (VINP) were added in 2001. Methods for the protocol using this survey technique were described in detail in the Seagrass Monitoring Protocol, Virgin Islands National Park (Muehlstein & Miller 2002). Initial comparisons of seagrass densities from fixed transect sampling and randomized sampling (using a $0.04m^2$ PVC quadrat), indicated few consistent differences between sampling methodologies (Beets and Muehlstein 2003) when seagrass short shoot densities were analyzed. The most notable advantages associated with AquaMap™ were the randomized sampling design and the ability to relocate sampling points within a one-meter accuracy and an expanded sampling area.

Data were summarized for all seagrass short shoot densities collected using randomized seagrass surveys (Table 2). Analysis of short shoot densities in Greater Lameshur Bay over the last five years indicated little dynamic change in the seagrass community (Figure 6). The densities of *T. testudinum* did not begin to approach densities found in the early to mid 1990s (Figure 1) suggesting the seagrass community is still in a recovery phase. In Brown Bay (Figure 7) seagrass short shoot densities declined from 2003 to 2004. Large blowouts were apparent that were not previously present within the study site. These blowouts were mapped in 2004 for additional monitoring of the site. Four years of monitoring data in Hurricane Hole (Figure 8) indicated a steady increase of *T. testudinum* densities with a large decline in *S. filiforme*. This dynamics of this site will need further data collection and analysis.

Table 2. Summary of mean seagrass short shoot densities/meter^2 from randomized sample points. Standard deviations are indicated in parentheses. N=25 random sample points, 11 quadrats/sample point at each site.

Greater Lameshur Bay	**2000**	**2001**	**2002**	**2003**	**2004**
Thalassia testudinum	113.6 (160.1)	135.4 (125.4)	135.2 (201.4)	137.5 (200.0)	141.5 (190.8)
Syringodium filiforme	302.7 (289.7)	476.3 (343.0)	458.6 (366.1)	388.9 (246.4)	414.0 (285.5)
Halodule wrightii	8.7 (34.1)	32.7 (63.3)	33.6 (106.8)	54.2 (106.8)	18.5 (44.5)
Brown Bay		**2001**	**2002**	**2003**	**2004**
Thalassia testudinum		216.9 (172.1)	343.9 (233.6)	557.9 (441.5)	382.1 (225.2)
Syringodium filiforme		432.2 (308.9)	552.5 (369.9)	489.2 (484.9)	351.2 (220.5)
Halodule wrightii		140.6 (206.8)	207.8 (553.0)	79.5 (179.2)	75.7 (340.4)
Hurricane Hole		**2001**	**2002**	**2003**	**2004**
Thalassia testudinum		89.5 (175.7)	151.1 (300.2)	176.6 (294.9)	239.4 (362.5)
Syringodium filiforme		61.2 (182.2)	345.0 (1077.0)	62.6 (149.1)	98.8 (188.9)
Halodule wrightii		7.3 (36.4)	3.3 (16.4)	6.7 (21.4)	18.8 (65.3)

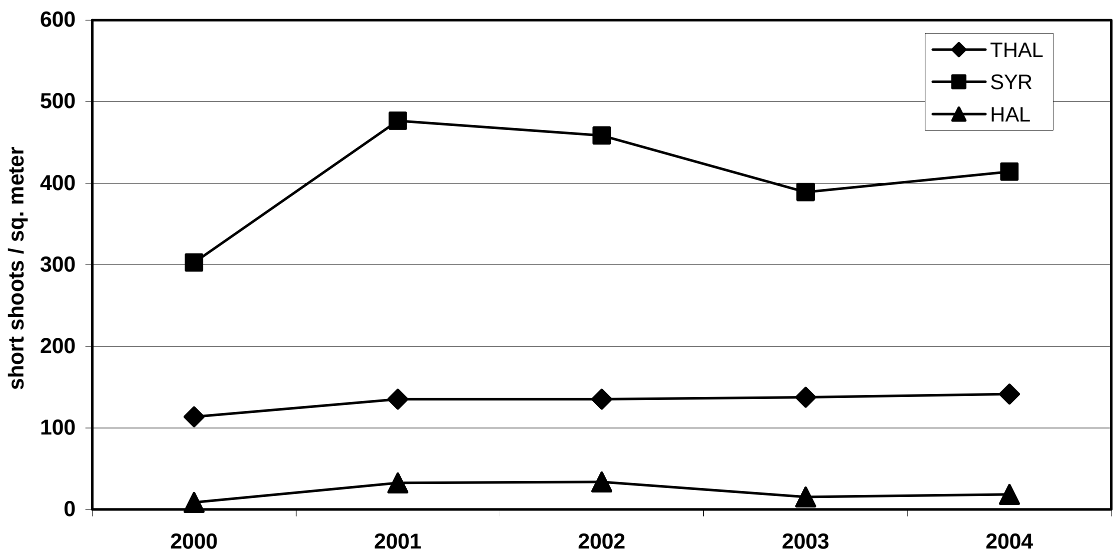

Figure 6. Mean short shoot densities of seagrasses in Greater Lameshur Bay (2000-2004) from randomized sample points. N=25 sample points, 11 quadrats/sample point.

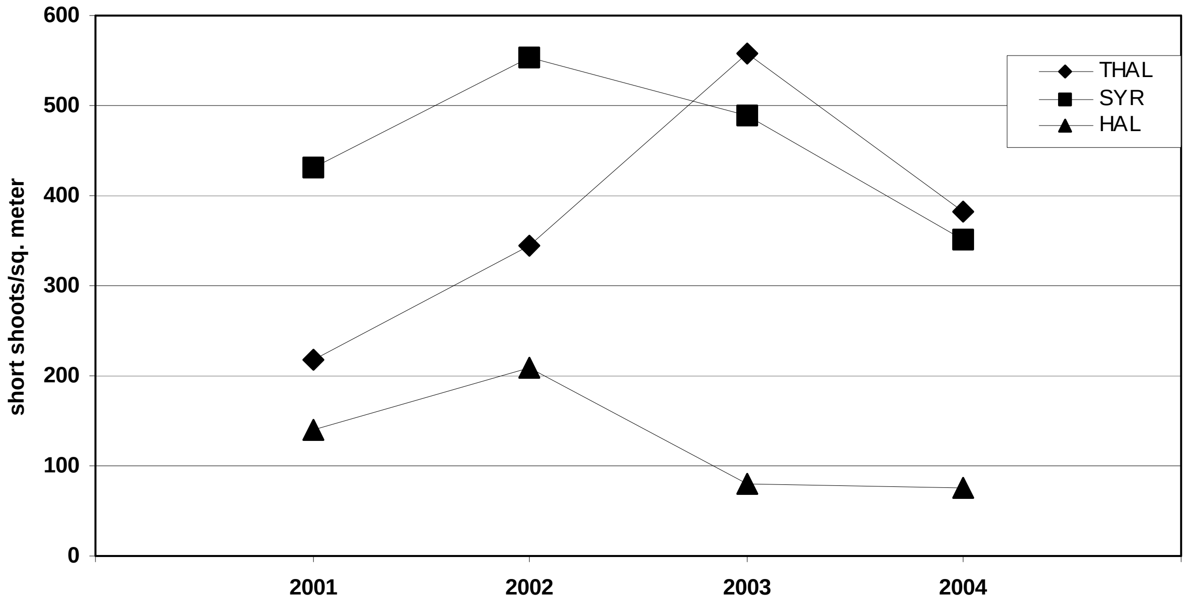

Figure 7. Mean short shoot densities of seagrasses in Brown Bay (2001-2004) from randomized sample points. N=25 sample points, 11 quadrats/sample point.

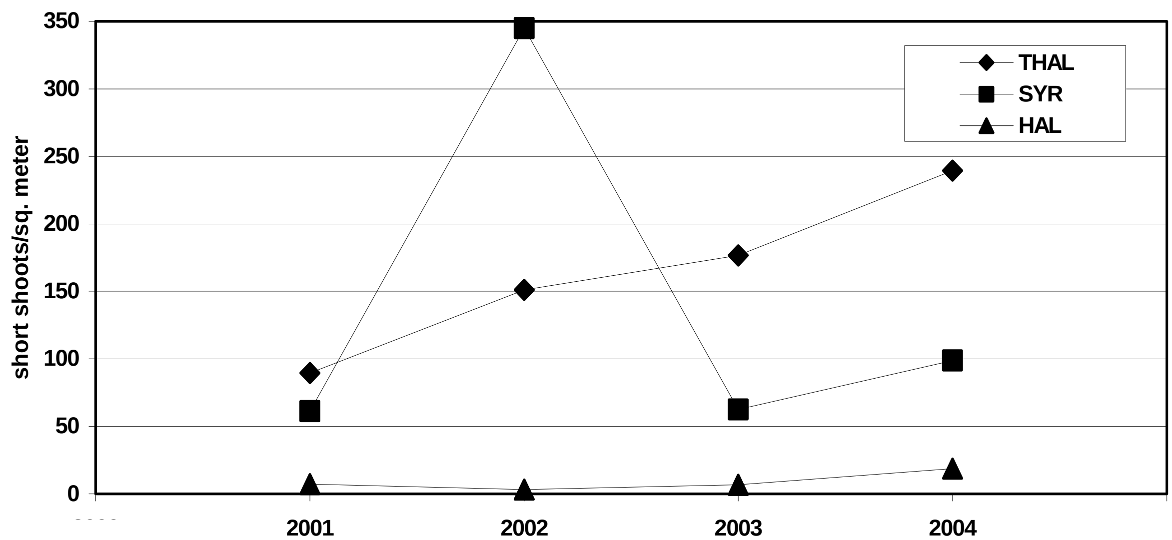

Figure 8. Mean short shoot densities of seagrasses in Hurricane Hole (2001-2004) from randomized sample points. N=25 sample points, 11 quadrats/sample point.

Seagrass Monitoring – VINP Vessel Moorings (2001 – 2004)
In 2001, the VINP Division of Resource Management established seagrass sampling at four sites (Francis Bay, Hawksnest Bay, Leinster Bay and Maho Bay) in association with the installation of additional permanent vessel moorings. Data management is handled by VINP however these data indicated some positive changes in seagrass densities.

Historical Seagrass Investigations and Summaries

Reports from the 1960s to present provided an overview of the presence of seagrass around the island of St. John (Table 3). Unfortunately no consistent methods of data collection (quantitative or qualitative) existed. In most cases, the historical data from the 1960s to the mid-1980s were purely qualitative observations and included mapping of seagrass habitats around the island. In the mid 1980s quantitative data collection for seagrasses were initiated.

Kumpf and Randall (1961) conducted dive sled snorkel tows around St. John and created a map of the benthic habitats. The map delineated general seagrass boundaries but did not provide any quantitative information (Table 3).

Beets et al. (1985) mapped the benthic habitats of sixteen sites around St. John in great detail using a combination of methods. Aerial photographs were utilized to prepare base maps. Each zone within the site was then verified and described using either snorkeling or SCUBA. Finally, quantitative and qualitative data were collected along a single transect across the site or multiple transects as needed with increased habitat complexity. Presences of eagrass species and their relative abundance were recorded. No quantitative data for seagrass densities were included (Table 3).

Two reports completed by School for Field Studies (Campbell et al. 1983; Singer 1987) provided a brief glimpse of seagrass densities and community structure for Greater Lameshur Bay. However, sample sizes were small (N=2) and generally limited to one sample date (Table 3). Data presented in the reports were difficult to interpret and analyses were not clear.

Williams (1988a,b) conducted a focused study in Maho and Francis Bays with some comparative work in Greater Lameshur Bay. This work provided the only productivity measurements for *Thalassia testudinum* around the island of St. John. Estimates of seagrass densities and community structure were also included in this study (Table 3).

Table 3. Summary of historical work around St. John, U.S. Virgin Islands.

Author(s) of Publication or Report	**Date of Study**	**Methods Utilized**	**Location**													
			Little Lameshur Bay	**Greater Lameshur Bay**	**Salt Pond Bay**	**Hurricane Hole**	**Brown Bay**	**Leinster Bay**	**Francis Bay**	**Maho Bay**	**Hawksnest Bay**	**Rendez- vous Bay**	**Reef Bay**	**Fish Bay**	**Cinnamon Bay**	**Caneel Bay**
Kumpff & Randall	1961	aerial photos & towed diving sled	seagrass present	seagrass present	site missing on map	site missing on map	site missing on map	seagrass present	seagrass present	seagrass present	seagrass present					
Campbell, Brady-Campbell & Levitan	1983	quadrats	seagrass present extensive cover	seagrass present extensive cover												
Beets, Lewand & Zullo	1985	transects; visual surveys	seagrass present	seagrass present			seagrass present	seagrass present	seagrass present	seagrass present extensive cover	seagrass present moderate cover					
Singer	1987	transects & quadrats		TH - 296 shoots/m2 SY - 220 shoots/m2												
Williams	VIRMC 1988	quadrats		TH - 262 shoots/m2					TH - 202 shoots/m2	TH - 123 shoots/m2	SY - 70 shoots/m2 H - 162 shoots/m2					
Muehlstein	1990 - present	transects & quadrats		seagrass present variable densities												
Muehlstein & VINP	1987	towed surveys	seagrass present moderate density		seagrass present moderate density		seagrass present high density	seagrass present low density	seagrass present low density	seagrass present low density	seagrass present low density	seagrass present low density	seagrass present high density	present sparse cover	present sparse cover	
Resource Management & Muehlstein	1997 - 2002	transects & quadrats	seagrass present moderate density		seagrass present moderate density		seagrass present moderate density									
Muehlstein & Miller	2003	AquaMap™ & quadrats		seagrass present mixed density		seagrass present mixed density	seagrass present mixed density									
Resource Management mooring project	2001- present	quadrats						seagrass present mixed density	seagrass present mixed density	seagrass present mixed density	seagrass present mixed density					
Rogers & Teytaud	1988	report of other work; no methods mentioned										seagrass present high density	seagrass present high density			present dense cover

Aerial Photographs

Aerial photographs from 1954, 1962, 1971, 1983, 1991, and 1994 dates were examined for Greater Lameshur Bay and Little Lameshur Bay. Approximate areal seagrass coverage was calculated from digitized images of seagrass habitat recorded from aerial photographs available at VINP Division of Resource Management (Table 4). A more intensive analysis was not possible for this report because the aerial photographs for these years have not been digitized and geo-referenced.

The percent change of areal cover among years in both bays is consistent over the forty-year period. When data were compared between maximum and minimum coverage years, the average change in percent cover was consistent. The fluctuation of seagrass cover is in Little Lameshur Bay was 21-22% among years and 19-23% among years in Greater Lameshur Bay. The consistent fluctuations in seagrass cover were coincidental with storm events and representative of the natural disturbance dynamics of seagrass communities. An increase in the frequency and severity of storms over the last decade decreases the chances for steady recovery periods within a seagrass community and supports the need for continuing long-term seagrass monitoring.

Table 4. Average area (m^2) of seagrasses from aerial photos.

Year	Little Lameshur Bay	Greater Lameshur Bay
1954	45,352	142,869
1962	52,042	137,170
1971	58,194	175,649
1983	45,334	144,080
1991	45,310	135,371
1994	57,074	170,606

Historical Seagrass Change

Historical changes of seagrass communities around St. John were relatively difficult to assess due to the lack of quantitative data. Qualitative data and comparative surveys provided a view of seagrasses in some areas declining over the last two decades. Some notable areas of change included Maho Bay and Francis Bay. Williams (1988a,b) indicated relatively dense patches of seagrasses in both bays. Towed surveys of both those bays, frequent snorkels of the bays and anecdotal information by numerous VINP personnel have indicated an almost complete loss of the seagrass in Maho and Francis Bays. Old survey pins from Williams' original project have also been relocated in bare sand instead of a dense seagrass patches. Anecdotal information from Kumpff and Randall (1961) also indicated extensive seagrass cover in Francis Bay at deeper depths that no longer exists. Salt Pond Bay was another bay noted for extensive seagrass cover historically. Although no historical quantitative or qualitative data existed, local knowledge of scientists supported a steady decline of seagrass cover in Salt Pond Bay over at least the last two decades.

The difficulty in assessing historical change in seagrass community structure supports the need for a comprehensive long-term monitoring program for this valuable coastal resource. Recovery time in seagrass communities following major disturbances is long, usually up to ten years. Long-term monitoring will provide valuable information for conservation and protection of seagrass communities and additional data supporting the ecosystem function and the link with coral reef fishes and coral reefs.

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REPORT SUMMARY

The primary goals of this project were to collect, review, summarize, and disseminate the available datasets for reef fishes and seagrasses around St. John, US Virgin Islands. We have summarized and synthesized information on available databases in this report, and provided the structure of those databases in the appendices.

The numerous investigations and monitoring projects conducted around St. John have documented the changes in reef fishes and seagrasses. Although large natural variability in marine resources have been documented, the general trends suggest resource declines as presented in previous investigations (Rogers and Beets 2001, Beets and Rogers 2002, Muehlstein and Miller 2002, Beets and Muehlstein 2003,Beets and Friedlander 2003).

Many changes go relatively undocumented in most tropical ecosystems and even unnoticed. Data acquisition and monitoring programs are frequently initiated following large resource changes. Although this is true for the US Virgin Islands, St. John has fortunately received much scientific investigation, primarily due to the funding and efforts of the US National Park Service. Historical data has been compared to monitoring data collected over the past 20 years to provide a view of marine resource changes over 60 years. This extended view supported previous conclusions of resource degradation and serial overfishing around St. John.

The recently established NPS Inventory and Monitoring Program and the NOAA/NOS Center for Coastal Monitoring and Assessment Program should provide future long-term monitoring data on reef fishes and seagrasses within Virgin Islands National Park, around St. John, and throughout the US Virgin Islands. Future assessments using data from these programs should provide more quantitative analyses for evaluating trends around St. John.